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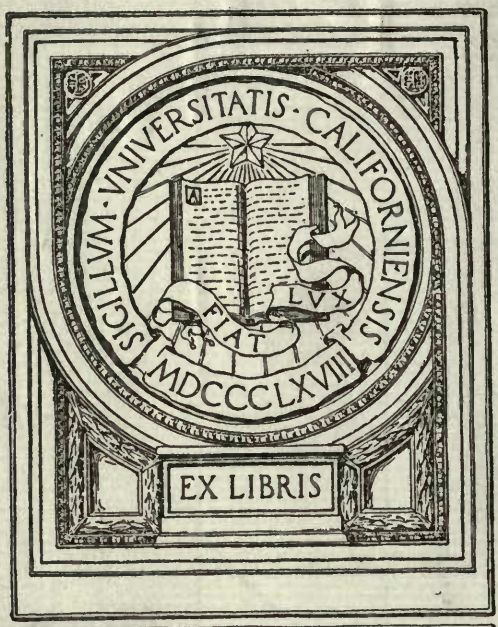
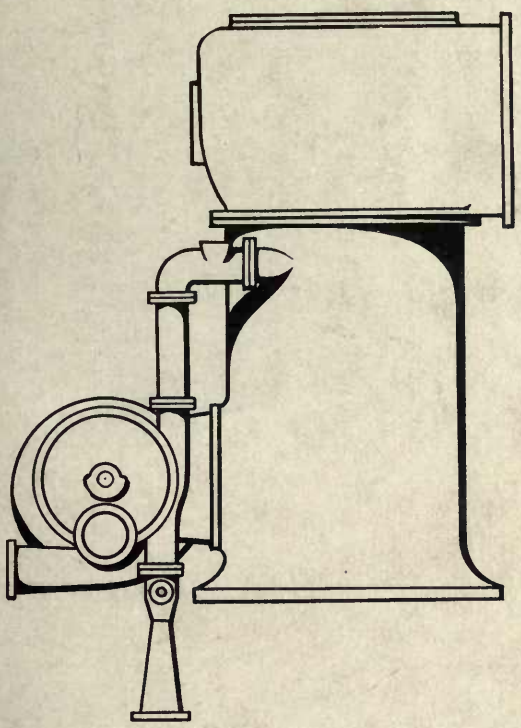
GIFT OF
Arthur E. Moncaster



The Westinghouse Machine Company

UNIV. OF

The Westinghouse-Leblanc

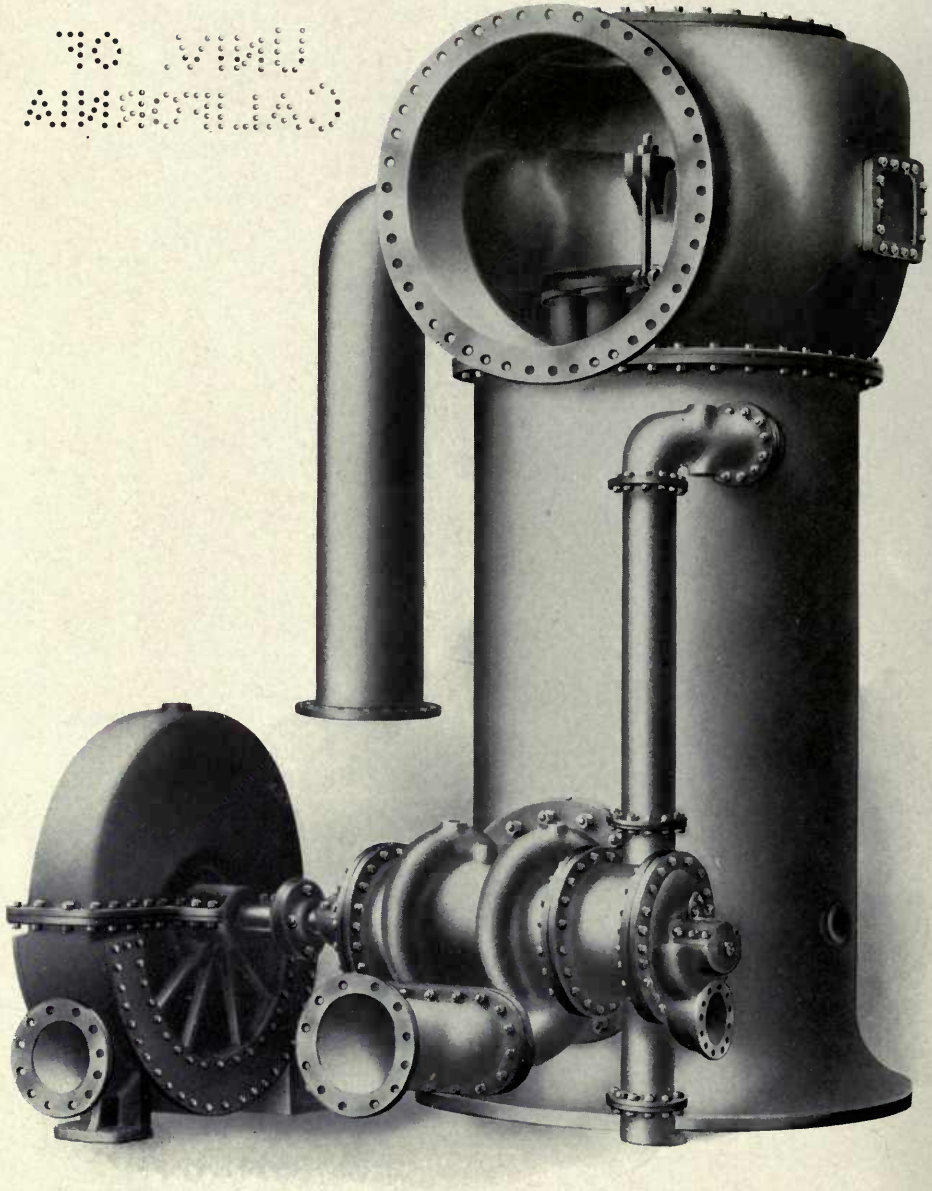


Condenser

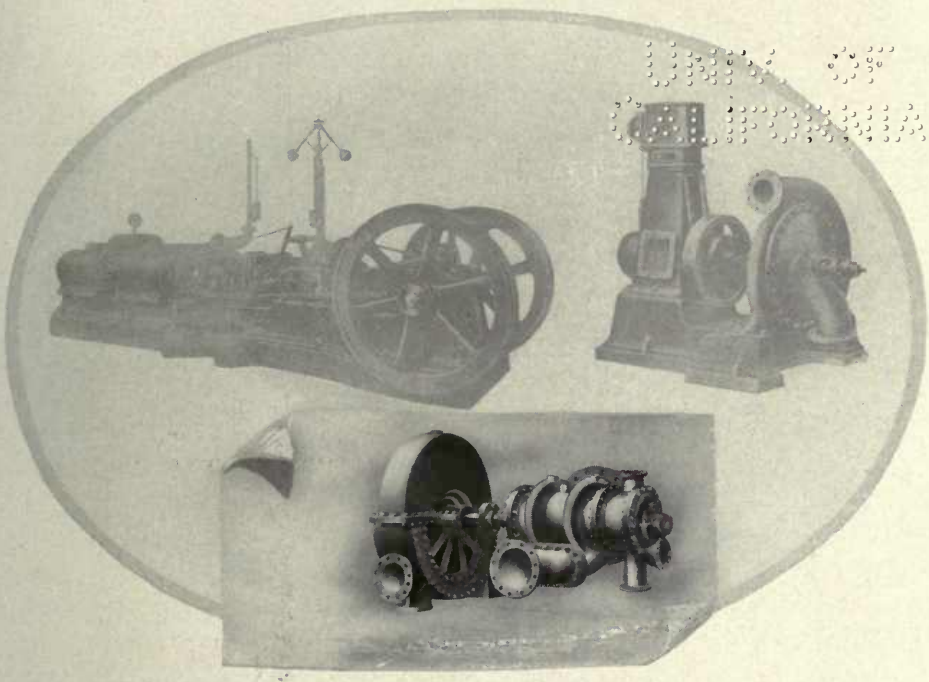
HUNT, MIRK & CO.
ENGINEERS
SAN FRANCISCO
Pacific Coast Representative

EAST PITTSBURG, PA.

Gift of Arthur E. Moncaster
W4



Westinghouse-Leblanc Condenser
Standard Jet Type
Driven by Westinghouse Steam Turbine



Relative sizes, air and circulating equipments of like capacity

The Westinghouse-Leblanc Condenser

The Type The Westinghouse-Leblanc Condenser represents one of those developments in engineering that owes its stimulus to a radical improvement in another branch of the art.

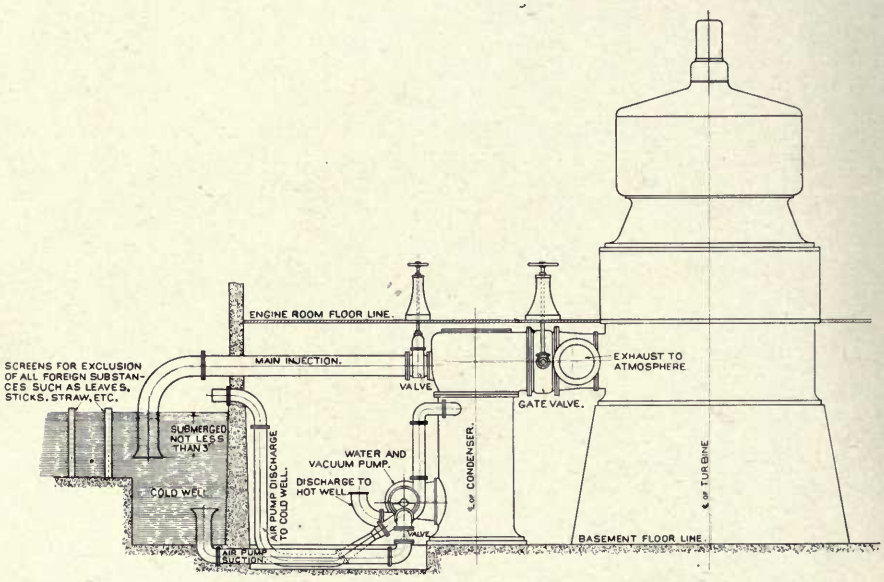
The steam turbine revolutionized steam engineering practice in half a dozen years. The Leblanc Condenser bears the same relation to the familiar type of condensing apparatus that the steam turbine does to the reciprocating engine. It is in fact a turbine type condenser. Like the turbine it occupies only a small fraction of the space formerly allotted. Like the turbine it develops superior efficiency, not by the multiplication of parts, but through a simple application of rotary motion, with no reciprocating or rubbing parts and no valves of any description.

726302

Recent Developments At the time of the introduction of the steam turbine by the Westinghouse Machine Company, it was announced that a very high vacuum would improve turbine economies to an extent hitherto impossible when applied to reciprocating engines. This condition naturally created an era of development among the condenser designers.

It became evident at once that the old types that were good enough for 25″ or 26″ vacuum would be practically useless where the requirements called for a vacuum of 28″ or 29″. While many refinements thus far have been made in all features of condenser design, they have been generally along the lines of former practice. The principal improvement adopted by practically all manufacturers has been to apply a separate dry vacuum pump for the removal of air and non-condensible vapors.

The dry vacuum pump, as commonly constructed, is a direct steam driven reciprocating unit, with its air cylinder and valve mechanism designed to reduce as far as possible the return to the condenser of the compressed air from the



Westinghouse-Leblanc Condenser serving a Curtiss Turbine at the plant of The Harwood Power Co., Harwood, Pa.

A cooling pond with Koerting sprays is used for cooling the injection water

clearance spaces. When it is realized that the air following back from the clearance will exceed many times the original volume, it becomes evident that the ideal vacuum will never be reached by the reciprocating type of pump.

In the effort to overcome these inherent defects, builders have resorted to numerous refinements. Air cylinders are water-jacketed to prevent overheating. Mechanically operated air valves are introduced to prevent the building up of a high back pressure in the condenser sufficient to lift voluntary valves from their seats. Two air cylinders are sometimes put in series, which manifestly improves the efficiency. An additional set of flash ports is sometimes introduced, which permits the air compressed in the clearance to be almost instantaneously discharged, not into the condenser, but into the opposite end of the cylinder just before the suction valves open. This last expedient would at first blush seem to go a long way toward removing the bad effect of clearance, if it did not in a measure defeat itself.

The sudden expansion resulting from this action causes a re-evaporation of the moisture always present on the walls of the cylinder, and hence, no air can enter from the condenser until the piston has traveled far enough to equalize the pressure.

The net result of the combination of such expedients is to impose a burden of first cost and maintenance that will overbalance the doubtful benefits to be secured by extreme complication.

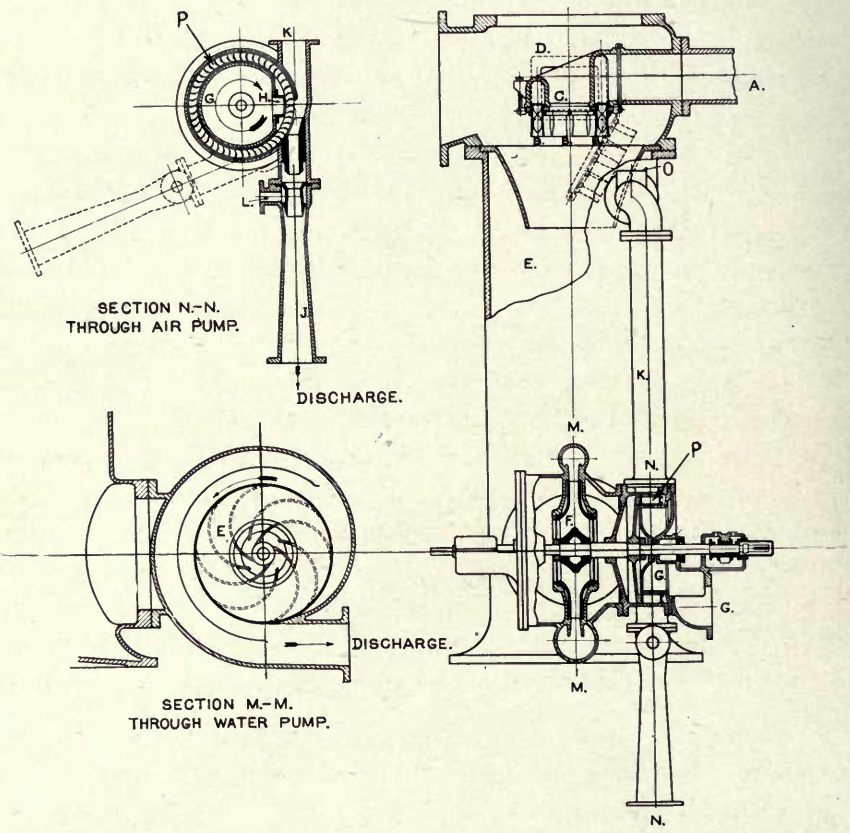
Essential Features

The most striking feature of the Leblanc system of condensation is its compactness and simplicity. While it employs the excellent feature of separate removal of water and air, its functions are performed by a pair of small turbine type rotors on a common shaft, in a single unit casing, which is integral with the lower portion of the condensing chamber.

The condensing chamber is of small diameter, being but slightly larger than the exhaust opening of the engine.

These elements are all discernible at a glance, but the pre-eminent superiority of the Leblanc system over all others lies in the practically perfect removal of air and non-condensible vapors.

The detailed description of the air pump on the following page shows how this result is obtained by a mechanism that is practically indestructible.



Sectional views of the standard Westinghouse-Leblanc Condenser are shown on the opposite page. Exhaust steam enters at D and cooling water entering through pipe A is projected downward through spray nozzles B. The injection water and condensed steam flow to the centrifugal discharge pump M under a head of 2 or 3 feet, which insures positive filling of the pump. The exhaust steam is drawn downward and condensed by the water spray. The space E above the water is occupied by water vapor plus the air released from the injection water and from the exhaust steam. This space communicates with the air pump N through pipe K.

The Air Pump

The principle is entirely new, and it differs from all ejector type pumps which depend on friction for the entrainment of air.

The Leblanc pump projects a series of water pistons through the discharge nozzles, each one of which forces ahead of it a small pocket of air.

This air, of course, mingles with the water in the lower portion of the nozzle, but the speed is such that no part of it ever finds its way back toward the condenser. In other words, there is no leakage past the pistons. The initial pocketing of the air between the successive layers of water is positive and, as will readily be seen, the neutralizing effect of clearance is entirely eliminated. The water supply for the air pump may be taken from the main water inlet or a supply may be placed in a tank and used over and over in the air pump. Since the air pump water is in communication with the condenser, it is drawn by suction into an annular chamber G, which is overhung by the buckets of the pump rotor P. The water passes out of the chamber through the ports H and is projected downward in a rapid succession of water pistons. At the lower end of the air pump nozzle is placed an auxiliary ejector nozzle L, to which is connected a steam pipe. In starting up the condenser, steam is turned into this auxiliary nozzle for a few moments, thus creating a sufficient vacuum to start the regular flow of water through the air pump.

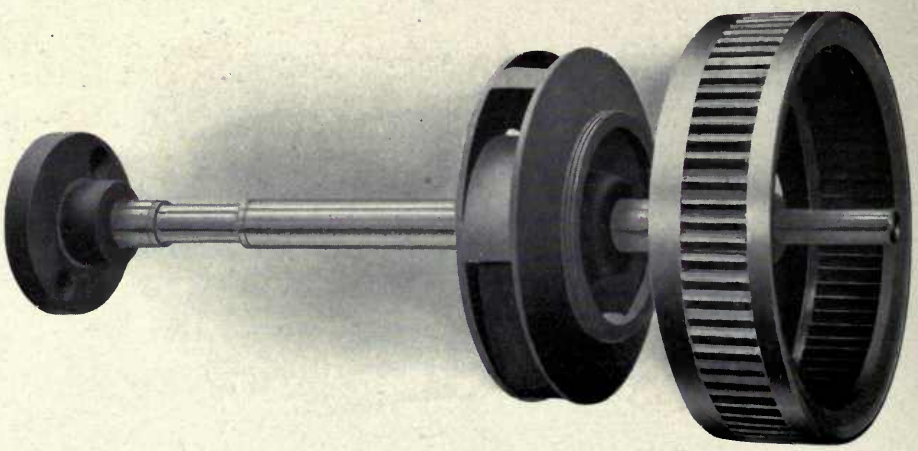
Where the level of the cold well is 3 or 4 feet above the basement floor, the air pump may be started without the use of steam.

As will be seen from the illustration, the air pump rotor P and the main pump runner F are enclosed in a common casing and mounted on the same shaft. There are only two bearings and the shaft glands are made air-tight by water seals.

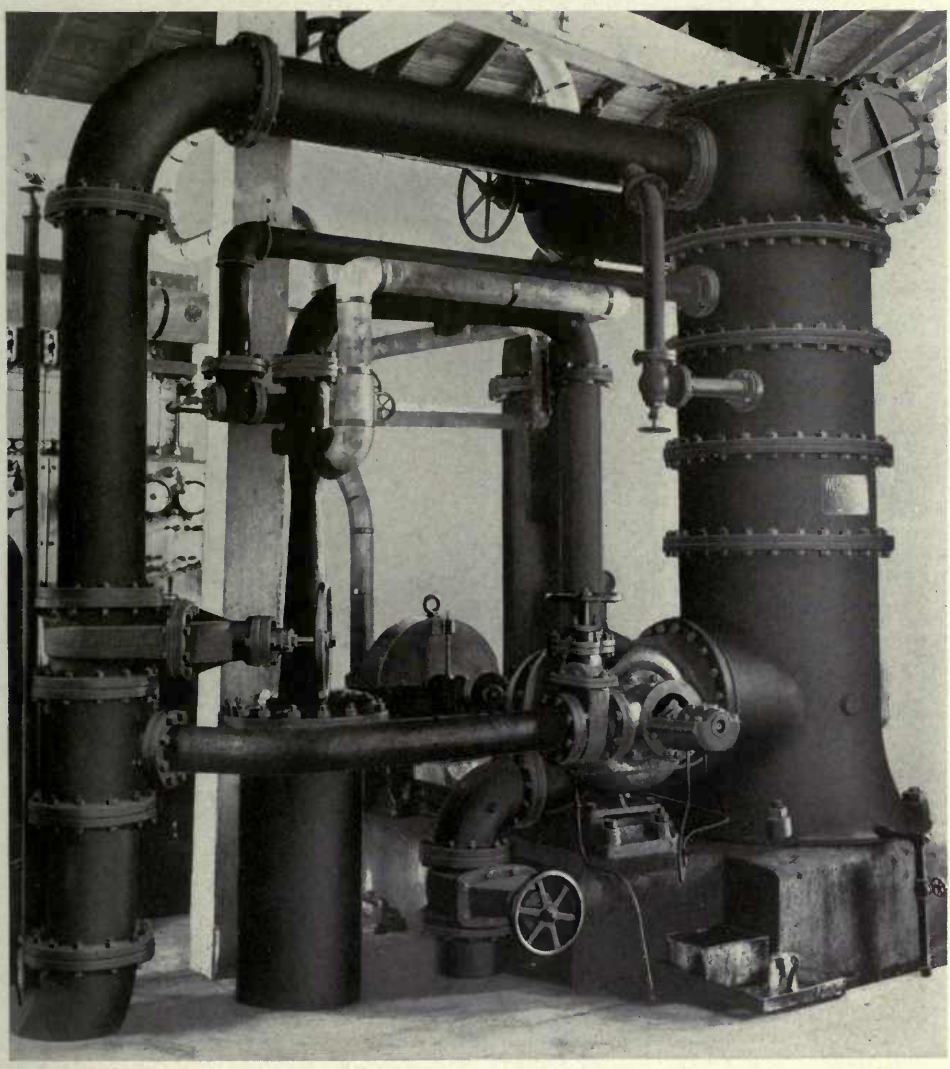
Power Requirements The pumps are usually driven by a Westinghouse steam turbine, and under ordinary conditions require from 2 to 3 per cent of the power generated by the main engine.

The exhaust from the condenser turbine is utilized for heating feed water, and when combined with the exhaust of other plant auxiliaries, the quantity is just about sufficient to maintain a feed temperature of 212 degrees Fahrenheit.

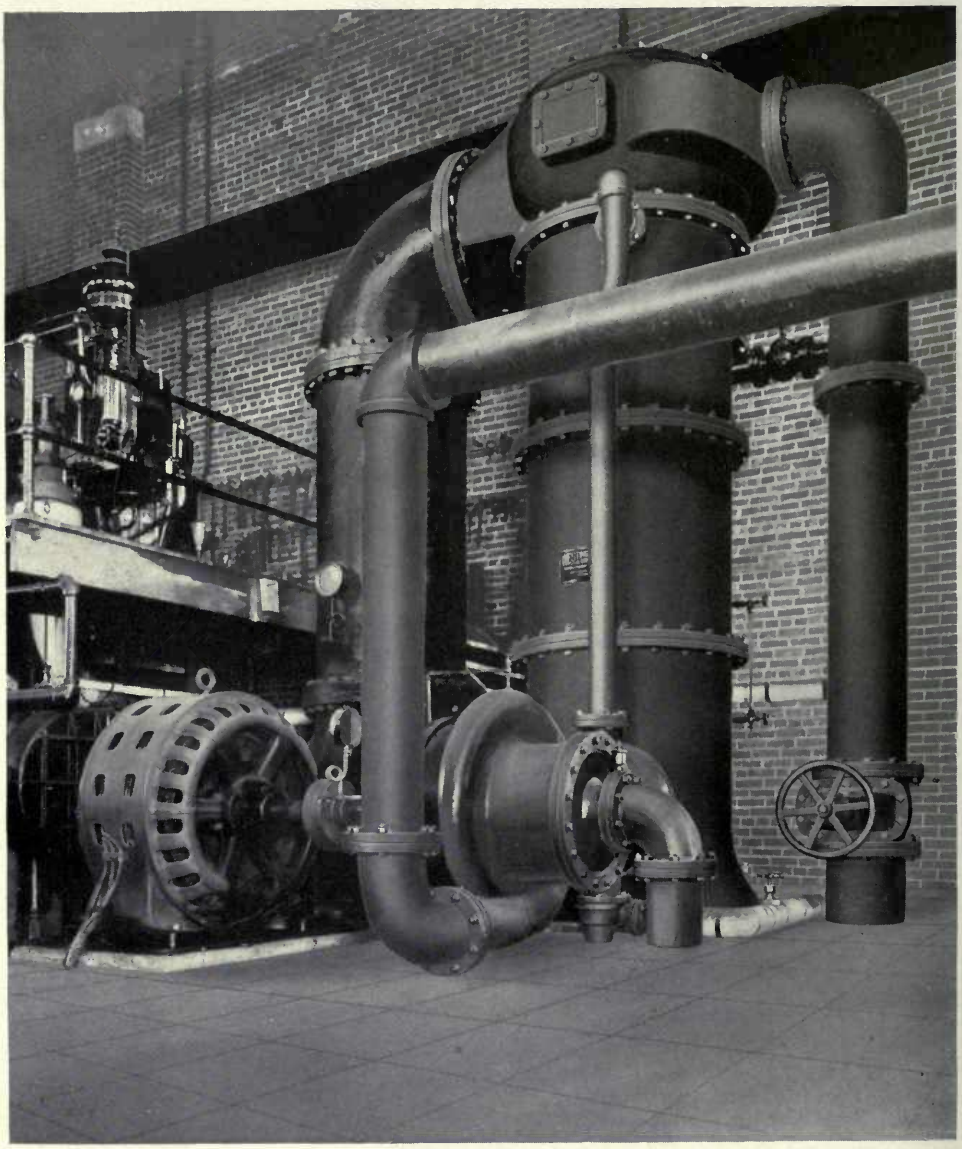
In cases where economizers are used, or where there may be extra sources of exhaust steam, it would be advisable to operate either the condenser pumps or the exciter by means of an electric motor. The main pump is commonly designed to discharge against only a few feet head sufficient to overcome friction in the discharge line. If it is desired to elevate the water to the top of cooling towers, or other moderate elevations, the pump can readily be modified to meet the additional duty.



This is the only moving element in the condenser



Turbine driven condenser at the plant of
the Bristol Gas & Electric Co., Bristol, Tenn.



Motor driven condenser at
the Municipal Lighting Plant of the City of Cleveland

This condenser serves a 1000 kw. Westinghouse Turbine, injection water being cooled in a ¾-acre pond with Koerting sprays—27½-inch vacuum is maintained at full load during summer

Counter Current Principle This term is often used in connection with various apparatus whose functions involve a transfer of heat. Aside from its application to surface condensers, it is generally ignored by jet condenser builders, although sometimes vaguely referred to. In general terms, it may be said that counter current principle as applied to a cooling process consists in so disposing the cooling medium that the substance being cooled will at the instant of withdrawal be subjected to the full effect of the lowest temperature. Thus, in a surface condenser the water is introduced at the top and the steam at the bottom, the steam, rising to the top, is exposed to the entering cold water. The air, which is always present, being non-condensible, is little affected by this final cooling, but the effect on the final volume of steam is remarkable, a much greater proportion of it being condensed in the cooler region and the air pump, instead of handling a certain volume of air plus a relatively large volume of steam, is enabled to draw out a mixture from which a large part of the steam as such has been eliminated. This law may be illustrated arithmetically as follows:

CASE I. Slight Counter Current Effect.

Assume initial temperature injection water	=	70°
Temperature at which air is removed	=	90°
Vacuum (temperature 101.3°)	=	28°
Weight of air entering condenser per minute	=	1 lb.

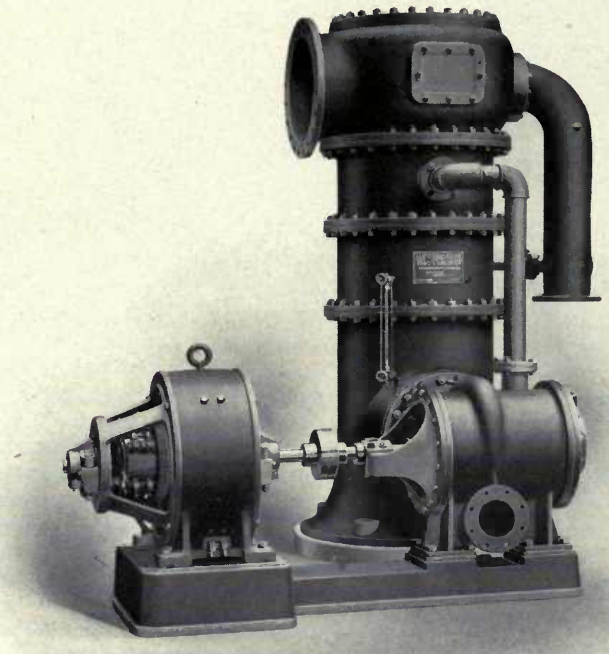
In this case, owing to an excess of cooling water as ordinarily supplied, the mixture of air and vapor is taken off in a partly cooled condition, i. e., from 101.3 degrees (the hottest point) to 90 degrees. At this temperature and pressure the volume of the pound of air alone is 221 cubic feet, while the volume of the steam is 539 cubic feet. Therefore, the air pump, in order to extract a pound of air per minute, must have an effective displacement of 221 cubic feet plus 539=750 cubic feet per minute.

CASE II. Full Counter Current Effect.

Assume initial temperature injection water	=	70°
Temperature at which air is removed	=	70°
Vacuum (temperature 101.3°)	=	28°
Weight of air entering condenser per minute	=	1 lb.

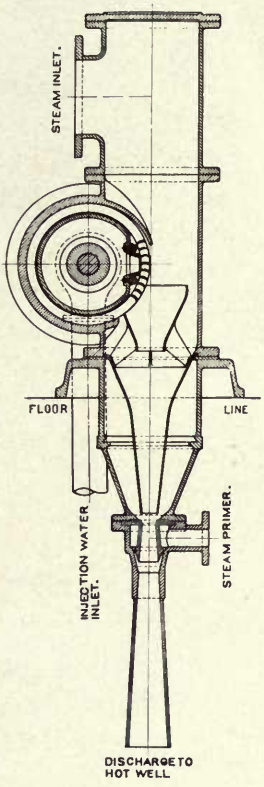
In this case, the full counter current effect is realized, the mixture of air and steam being taken off at 70 degrees temperature (a cooling of 31.3 degrees below the hottest part). At 70 degrees the volume of one pound of air alone is 213 cubic feet, while the volume of steam in the mixture is only 125 cubic feet, making a total of 338 cubic feet for the air pump to handle, or less than half the size required for case I.

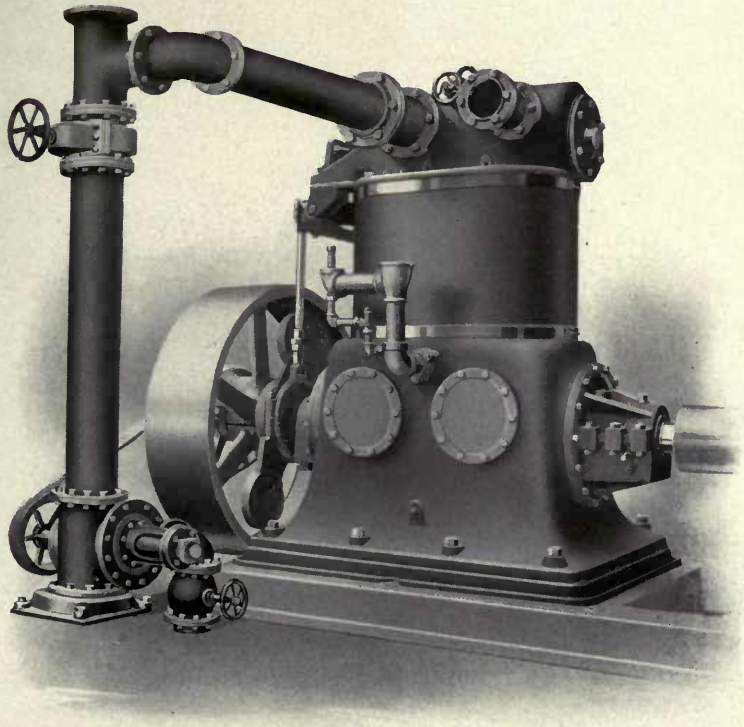
These relationships remain the same whether the cooling is done in a surface or a jet condenser, and the Leblanc air pump, as applied to either type, combines in its cold circulating water both the means of expelling the air and simultaneously cooling the mixture to the point of minimum volume.



Small Sizes For units smaller than 300 horse power, it is customary to eliminate the main condensing chamber and pass all of the exhaust steam as well as the air through the air pump only. For this service, the air pump is slightly modified, a relatively greater amount of water being used, which serves both to expel the air and condense the steam in one operation. The sectional cut illustrates a complete condenser of this type.

The same high efficiency is maintained and the apparatus occupies scarcely more space than that required for the exhaust pipe alone. The accompanying cut illustrates a vertical steam engine equipped with one of these small condensers.





Separate Air Pumps

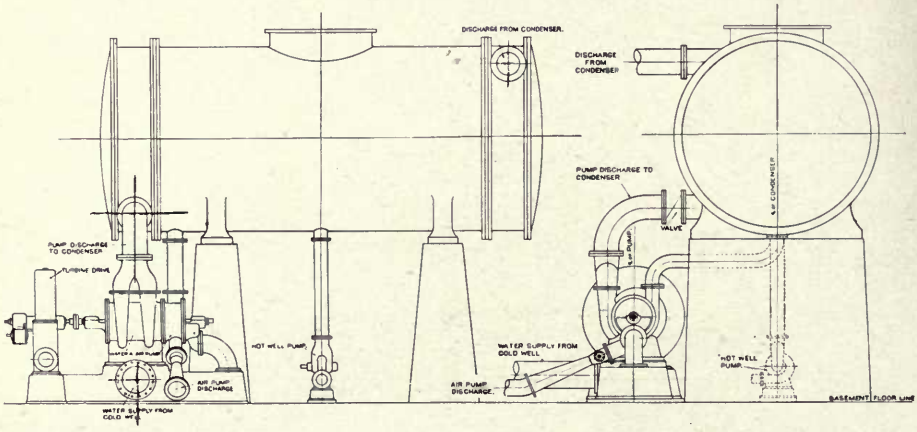
For use with surface condensers, both stationary and marine, and for application to barometric and other types of jet condensers, evaporating pans, etc., the air pump is furnished separately. Embodying, as it does, the vital element of the Leblanc system, its application in any situation requiring an efficient vacuum will insure a marked improvement in the effectiveness of the entire equipment.

In the case of new installations of surface condensers, the air pump and the circulating pump may be combined in a single compact unit substantially as shown by the cut below.

Success Abroad

It is not always logical to refer to European practice as a criterion to be precisely followed in America, for the reason that labor cost is lower and fuel cost much higher and, therefore, warrant the use of expensive and elaborate equipment which would fail to realize any ultimate economy when transplanted in the region of lower fuel cost and higher labor. In the present instance, however, where the whole tendency is in the direction of simplicity and ease of handling, the fact of the rapid adoption of the Leblanc system in England and on the Continent possesses a useful significance for American practice.

There are upwards of 400 installations in Europe, aggregating one-half million horse power, many of the most prominent engine and turbine builders, including Prof. Rateau, having abandoned the older types formerly manufactured by themselves and are installing the Leblanc system exclusively. Mr. Balcke, of Bochum, Germany, probably the largest con-



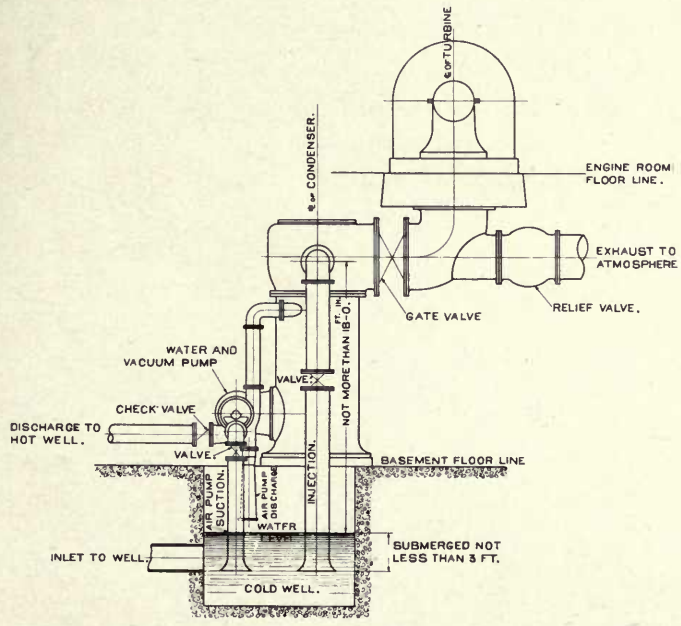
denser builder in Europe, is now turning out the Leblanc type exclusively, under a license arrangement. Naturally, the majority of these installations are in connection with steam turbines of various makes, but a considerable proportion is applied to stationary reciprocating engines, marine engines, vacuum pans, etc.

The First Year's Showing At the present writing there has already been contracted for in this country over 60 Leblanc Condensers, aggregating 75,000 horse power. Most of these serve turbines of various types, while a few, especially in small sizes, are used with reciprocating engines.

Results obtained from some of these plants are set forth in the following tables.

Efficiency is here expressed by the percentage of an ideally perfect vacuum actually obtained. For instance, if the discharge temperature is 100 degrees Fahrenheit, the corresponding ideal vacuum would be 28.08 inches. If, however, the observed vacuum is 27.75 inches, the efficiency percentage would be

$$\frac{27.75}{28.08} = 98.8\%$$



Shop Test—East Pittsburg

No. 12 Condenser—Capacity and Efficiency

Steam Condensed Lbs. Per Hour	Temperatures		Vacuum Referred to a 30" Barometer	Per Cent of Ideal Vacuum
	Injection	Discharge		
11,400	65	79	28.76	99.5
18,300	70	92	28.09	98.8
25,000	71	97	27.96	99.3
32,100	70	104	27.59	99.3
38,600	70	112	26.81	98.8
11,300	55.3	72	29.06	99.5
18,400	56.5	86.3	28.44	99.4
25,000	62.3	94	28.21	99.7
32,100	65.5	103	27.51	99.0
37,500	54.0	102	27.56	99.0

Jersey Central Traction Company, Keyport, New Jersey

No. 5 Condenser—Capacity and Efficiency

(Rated capacity 8380 lbs. steam condensed at 27" vacuum and 90 degrees injection temperature)

Steam Condensed Lbs. Per Hour	Temperatures		Vacuum Referred to a 30" Barometer	Per Cent of Ideal Vacuum
	Injection	Discharge		
5,680	85.5	100.5	27.8	99.1
9,200	87.0	108.0	27.3	99.1
12,000	88.0	120.0	26.4	99.4
15,000	87.0	124.0	26.1	99.7
19,000	87.0	139.0	24.0	98.9

Union Sand and Material Company

No. 5 Condenser—Efficiency Only

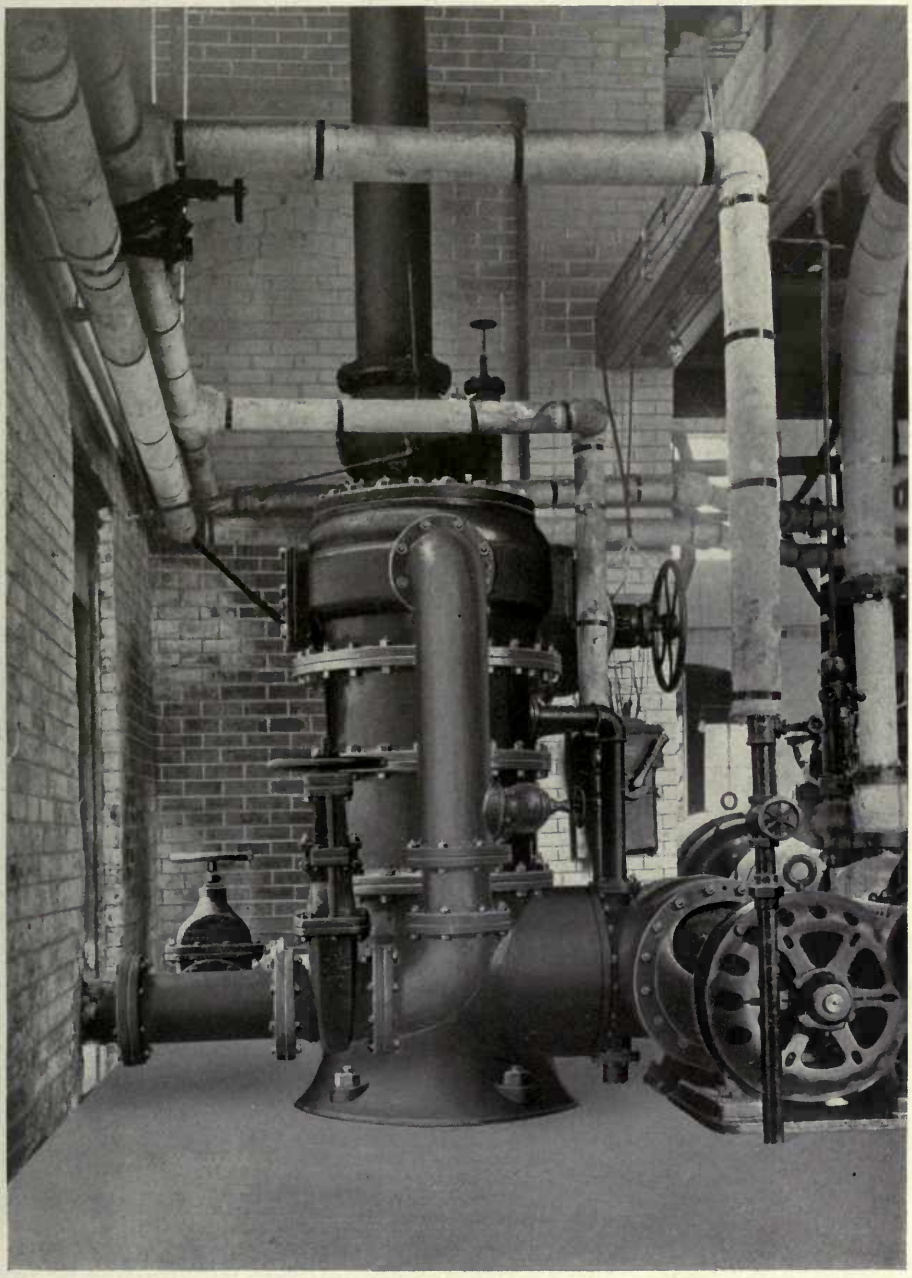
Temperature Discharge	Vacuum Referred to a 30" Barometer	Per Cent of Ideal Vacuum
75	28.9	99.2
80	28.7	99.1
82	28.7	99.3
78	28.6	98.5

(Practically full load was maintained during the above readings, viz., from 450 to 525 kilowatts on the turbine)

Jacksonville Oil Mill Co., Jacksonville, Ala.

No. 1 Condenser—Efficiency Only

Temperature Discharge	Vacuum Referred to a 30" Barometer	Per Cent of Ideal Vacuum
102	27.86	99.6
106	27.66	99.8
95	28.18	99.5



500 kw. condenser at the plant of
the Calhoun Light & Power Co., Jacksonville, Ala.

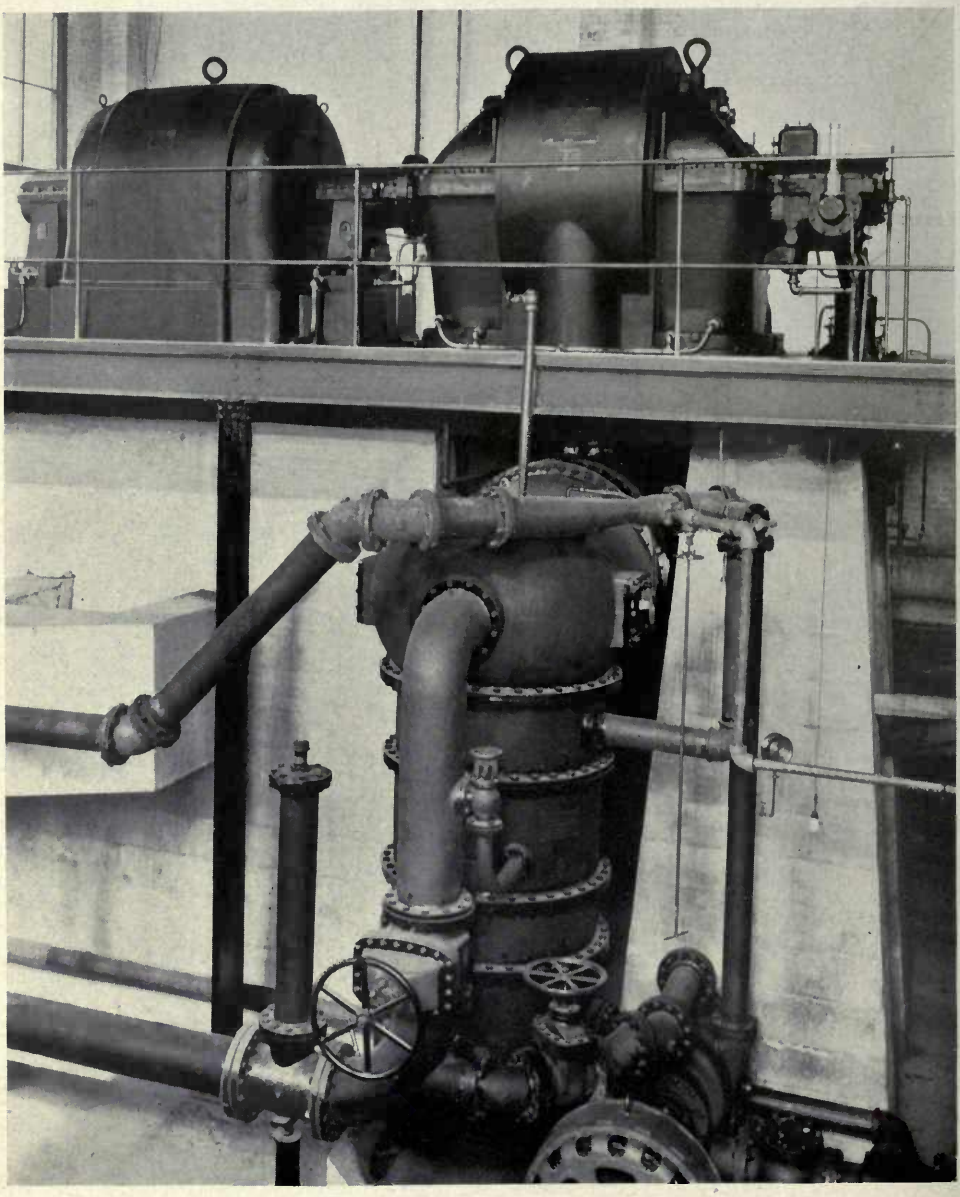
Relation between temperature and pressure of saturated steam

TEMPERATURE Deg. Fahr.	PRESSURE Lbs. Absolute	VACUUM in inches referred to a 30" Barometer	TEMPERATURE Deg. Fahr.	PRESSURE Lbs. Absolute	VACUUM in inches referred to a 30" Barometer	TEMPERATURE Deg. Fahr.	PRESSURE Lbs. Absolute	VACUUM in inches referred to a 30" Barometer	TEMPERATURE Deg. Fahr.	PRESSURE Lbs. Absolute	VACUUM in inches referred to a 30" Barometer
70	0.3602	29.27	90	0.6925	28.59	110	1.2663	27.42	130	2.2119	25.50
71	0.3726	29.24	91	0.7146	28.55	111	1.3035	27.35	131	2.2719	25.38
72	0.3854	29.22	92	0.7372	28.50	112	1.3416	27.27	132	2.3333	25.25
73	0.3986	29.19	93	0.7605	28.45	113	1.3807	27.19	133	2.3961	25.12
74	0.4122	29.16	94	0.7844	28.40	114	1.4207	27.11	134	2.4603	24.99
75	0.4262	29.13	95	0.8090	28.35	115	1.4618	27.02	135	2.5261	24.86
76	0.4406	29.10	96	0.8342	28.30	116	1.5039	26.94	136	2.5932	24.72
77	0.4555	29.07	97	0.8601	28.25	117	1.5470	26.85	137	2.6619	24.58
78	0.4708	29.04	98	0.8867	28.20	118	1.5912	26.76	138	2.7321	24.44
79	0.4865	29.01	99	0.9140	28.14	119	1.6364	26.67	139	2.8040	24.29
80	0.5027	28.98	100	0.9421	28.08	120	1.6828	26.58	140	2.8774	24.15
81	0.5194	28.94	101	0.9709	28.02	121	1.7302	26.48	141	2.9525	23.99
82	0.5365	28.91	102	1.0004	27.96	122	1.7789	26.37	142	3.0292	23.84
83	0.5542	28.87	103	1.0307	27.90	123	1.8287	26.28	143	3.1076	23.68
84	0.5723	28.84	104	1.0619	27.84	124	1.8797	26.18	144	3.1877	23.51
85	0.5910	28.80	105	1.0938	27.77	125	1.9318	26.07	145	3.2696	23.35
86	0.6102	28.76	106	1.1266	27.71	126	1.9852	25.96	146	3.3532	23.18
87	0.6299	28.72	107	1.1602	27.64	127	2.0399	25.85	147	3.4387	23.00
88	0.6502	28.68	108	1.1947	27.57	128	2.0959	25.74	148	3.5260	22.83
89	0.6711	28.63	109	1.2301	27.50	129	2.1533	25.62	149	3.6152	22.64

The above vacua are referred to a barometer of 30 inches. In taking vacuum readings, a barometer reading at the same level as the condenser should be obtained, and in comparing temperatures allowance should be made for the barometer, adding or subtracting, as the case may be, the difference between the barometer readings and 30 inches. Thus, if the barometer reading is 30.3 inches, for example, subtract 0.3 inches from the vacuum reading to get the correct vacuum. If the barometer reads 29.6, for example, then add 0.4 to the vacuum reading to get the correct vacuum.

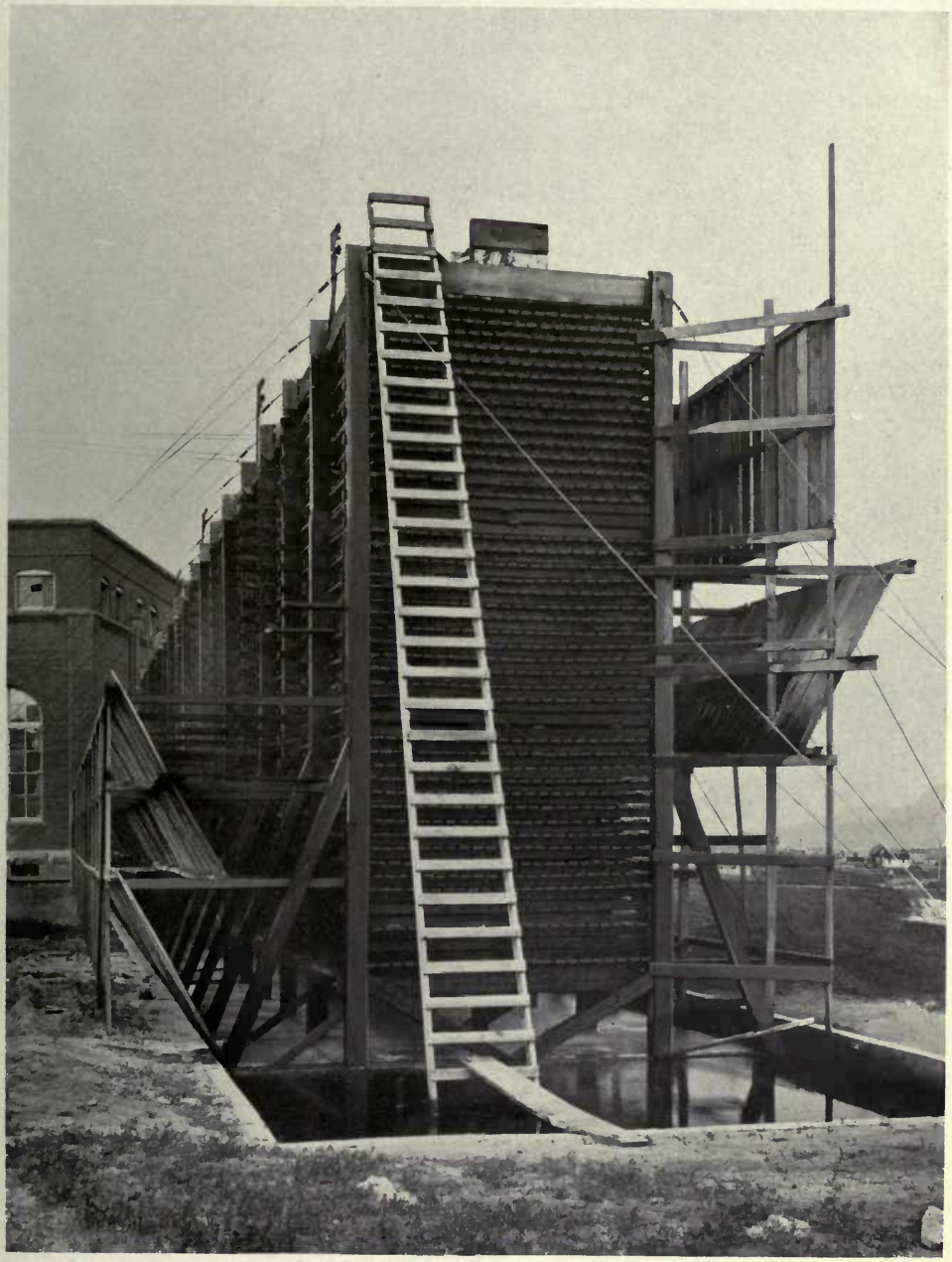
Relative volumes of air in a saturate mixture—at various temperatures—corresponding to different observed vacua

Temperature Deg. Fahr.	Pounds per Square Inch Absolute, no Air Present	Inches Vacuum Referred to a 30" Barometer, no Air Present	Pounds per Square Inch Absolute						
			.49	.98	1.47	1.96	2.45	2.94	14.697
			Inches Vacuum Referred to a 30" Barometer						
			29	28	27	26	25	24	0
			Per Cent Volume of Saturated Air Present in a Mixture of Air and Vapor of Water						
60	0.2545	29.48	48.0	74.0	82.6	87.0	89.5	91.4	98.4
70	0.3602	29.26	26.5	63.0	75.5	81.5	85.5	87.8	97.6
80	0.5027	28.97	.....	48.6	65.8	74.3	79.5	82.9	96.7
90	0.6925	28.59	.....	29.4	52.9	64.6	71.8	76.4	95.4
95	0.8090	28.35	.....	17.4	45.0	58.7	67.0	72.5	94.6
100	0.9421	28.08	.....	3.87	35.9	51.9	61.5	67.9	93.7
105	1.0938	27.77	.....	.....	25.6	44.2	55.3	62.8	92.6
110	1.2663	27.42	.....	.....	13.8	35.4	48.3	56.9	91.4
112	1.3416	27.26	.....	.....	8.7	31.6	45.3	54.4	90.9
114	1.4207	27.10	.....	.....	3.3	27.5	42.0	51.6	90.4
116	1.5039	26.93	.....	.....	.....	23.3	38.6	48.9	89.8
118	1.5912	26.75	.....	.....	.....	18.8	35.05	45.85	89.3
120	1.6828	26.57	.....	.....	.....	14.1	31.3	42.8	88.6
122	1.7789	26.37	.....	.....	.....	9.3	27.4	39.5	88.0
124	1.8797	26.17	.....	.....	.....	4.1	23.3	36.1	87.3
126	1.9852	25.95	.....	.....	.....	.....	18.96	32.5	86.6
128	2.0959	25.73	.....	.....	.....	.....	14.45	28.7	85.8
130	2.2119	25.48	.....	.....	.....	.....	9.72	24.8	85.0
132	2.3333	25.24	.....	.....	.....	.....	4.77	20.6	84.2
134	2.4603	24.90	.....	.....	.....	.....	.....	16.3	83.3
136	2.5932	24.71	.....	.....	.....	.....	.....	11.8	82.5
138	2.7321	24.42	.....	.....	.....	.....	.....	7.07	81.5
140	2.8774	24.13	.....	.....	.....	.....	.....	2.13	80.5



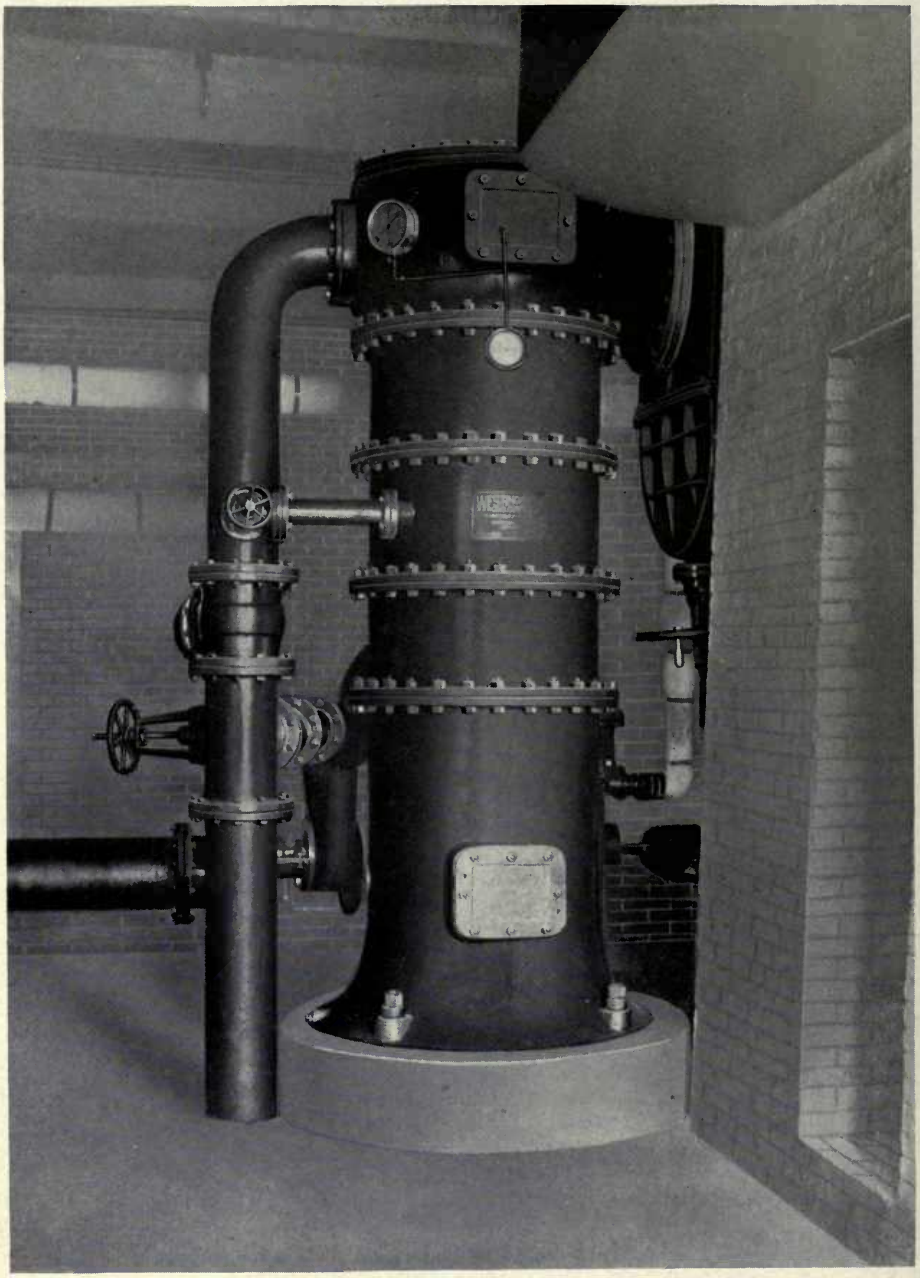
An Interesting Installation

A 1000 kw. Westinghouse Exhaust Steam Turbine, with a Leblanc Condenser working in connection with a cooling tower at the plant of the Colorado Springs Electric Company, Colorado Springs, Col.



Cooling tower used in connection with the low pressure turbine and Westinghouse-Leblanc Condenser shown on the opposite page

It is needless to remark that the free use of artificial cooling devices is made a commercial success only by combining with a highly efficient condensing equipment



A typical installation of a 500-kilowatt
Westinghouse-Leblanc turbine-driven condenser

The Westinghouse Machine Company

General Offices, Works and Laboratory

East Pittsburg, Pa.

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